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SONIC SCATTERING BY BIOLOGICAL ENTITIES IN THE COASTAL WATERS O--ETC(U)

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SONIC SCATTERING BY BIOLOGICAL ENTITIES IN THE COASTAL WATERS OFF MISSION BEACH, CALIFORNIA

by

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This memorandum reports preliminary observations of sonic scattering taken at the NEL oceanographic tower and offers tentative explanations of the results. Further observations are required to substantiate the explanations before a formal report is prepared. The purpose of the memorandum is to record these results for comparison with future work at NEL and is intended for use of NEL workers.

*This work was conducted while employed as a student assistant during the summer of 1959.

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by

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ABSTRACT

An upward directed echo sounder was placed on the ocean floor off Mission Beach, California, in the summer of 1959, to determine the nature of sound scattering in the vertical column of water. Scattering density showed a pronounced increase in nighttime periods, with the scattering bodies exhibiting (1) unusual characteristics of movement, and (2) reactions to temperature and light stimuli. The scatterers, determined to be of a biological nature, appeared each evening with unfailing regularity in an unusually short period of time, and remained throughout the night until early dawn. In addition to the acoustic data, records of vertical temperature structure and visual and filmed observations were obtained, showing the possibility that the night interference effect, as it has become known, could be caused by swarms of shrimp-like mysids. Schools of fishes of several different varieties were also observed in the water and simultaneously recorded by the echo ranger.

INTRODUCTION

Many reports have been written on the phenomena of organic sound scatterers in the ocean (see references). However, most of the available

literature concerns itself with deep-water scattering, while relatively little research has been done on the more dynamic and unpredictable conditions of the shallow coastal regions. (Refs. 5 and 6 describe some of the shallow-water work that has been accomplished) the intent of the study described in this report, therefore, was to gain an insight into the "acoustic environment" of certain offshore waters, the specific purpose being to determine the presence and nature of any sound scattering bodies found in such an area. The new oceanographic research tower off Mission Beach, California, resting on a gently sloping, sandy-bottom in 60 feet (MSL) of water (Ref. 13) was selected as a suitable site for the studies. In July 1959, transducers for a sonic echo ranger were mounted face up on a tripod structure and lowered to the bottom near the tower.

EQUIPMENT

Acoustic

U. S. Navy NK-1 and NK-7 echo sounders were used to obtain acoustic data because of their ability to operate relatively free of serious breakdowns for long periods of time. The transmitting and receiving transducers, separated on these instruments, were mounted rigidly side-by-side on a tripod which held them 4 feet from the bottom. Figure 1 is a photograph of the transducer and tripod assembly. The transducers are magnetostrictive, double-ended radiators made of pure nickel laminations wound with several turns of heavy gauge wire. The surfaces facing the bottom on each transducer

Figure 1. Photograph of the tripod, with the receiving and transmitting transducers in place prior to its being placed on the ocean floor.

are covered with sound absorbing rubber to minimize bottom reverberations. Radiating surfaces on the transmitter and receiver are 3 3/8 X 6 inch rectangles. The signal is a pulse-type, keyed approximately 3 times per second, and operates at a frequency of 21 kilocycles per second. The main beam of the sound pattern is, roughly, 30 degrees wide at the 6 db down points in the plane of greatest directivity which, for this shape of radiator, would be in the direction parallel to the longest side of the transducer. Because of the rectangular shape, directivity is not symmetrical and some minor side lobe effects in the sound pattern are present.

The trace is recorded on a sensitized chart paper by a rotating stylus, which unfortunately utilized only a third of the width of the chart paper for the depth at the tower. The NK-1 was used for all records taken before 1 August 1959, when it was replaced by the newer model, the NK-7. The NK-7 has a somewhat improved signal generator and keying system; both are alike as far as signal characteristics are concerned. The transducer tripod was located approximately 50 feet suuth and west of the tower on the sea floor.

Temperature

Thermistor beads, encased in plastic, were used for temperature sensors. Approximately twenty beads were usually in operation, providing information, accurate to a tenth of a degree, for intervals of every 3 feet from bottom to surface. Two BROWN servo-recorders, a six-channel and a sixteen-channel, transcribed the data. An isotherm follower instrument

was used quite effectively to observe variations in temperature structure. This device has a "temperature seeking" sensing head, lowered into the water from a boom. The instrument records vertical fluctuations of an isotherm caused by water mass movements and internal waves.

Other Equipment

A Cruase-Hinds, type ABF-14, spotlight on the tower provided the means for testing the reactions of biological scattering bodies to light. The spotlight is mounted on the southwest corner of the tower, approximately 30 feet above the water and was trained on the ocean surface over the transducer at an angle of incidence of about 40 degrees. In addition, most of the ordinary oceanographic and meteorological equipment was available and was used from time to time to provide correlative and substantiating data.

OBSERVATIONS

At the time the NK-1 transducer was first placed on the ocean floor near the tower, daily periods of continuous operation, taken during the normal daylight working hours, showed very little of the expected returns between the bottom and surface echoes. Occasionally, short-lived returns were received at various depths, some of these indicating vertical movement towards or away from the transducer. These were believed to be medium to large-sised individual fish, but no positive identification as to type or species could be obtained.

During the first nighttime operation at the tower, however, the original fears that the equipment was inadequate for the type of measurement desired were quickly dispelled. Heavy scattering in the water column was discovered to appear very suddenly every evening, lasting throughout the night until morning. The fact that no returns has been received during the day and the record was nearly obscured at night showed the effect to be caused by some gross change in the acoustic medium. Following are descriptions of various nights spent at the tower during the summer.

Period of 6 July to 10 July 1959

A continuous four-day operation began on Monday, 6 July 1959, and terminated at noon, Friday, 10 July. During the day, Monday, very little was recorded, indicating that as far as the NK-1 sounder was concerned, the sea was free from scatterers. After sundown, however, conditions suddenly changed. Within a period of a few minutes between 2025 and 2035, heavy returns developed at about mid-depth, indicating the arrival of some sort of scatterers in the water column. Figures (2a) and (2b) show the 6 July record. The scattering objects formed into a well-defined layer at 2108 and, although the layer lasted for only a period of approximately 6 hours, the recording of the scatterers throughout the water column, nevertheless, continued without a break until a few hours before dawn.

A short time after the layer had formed, a definite reaction to

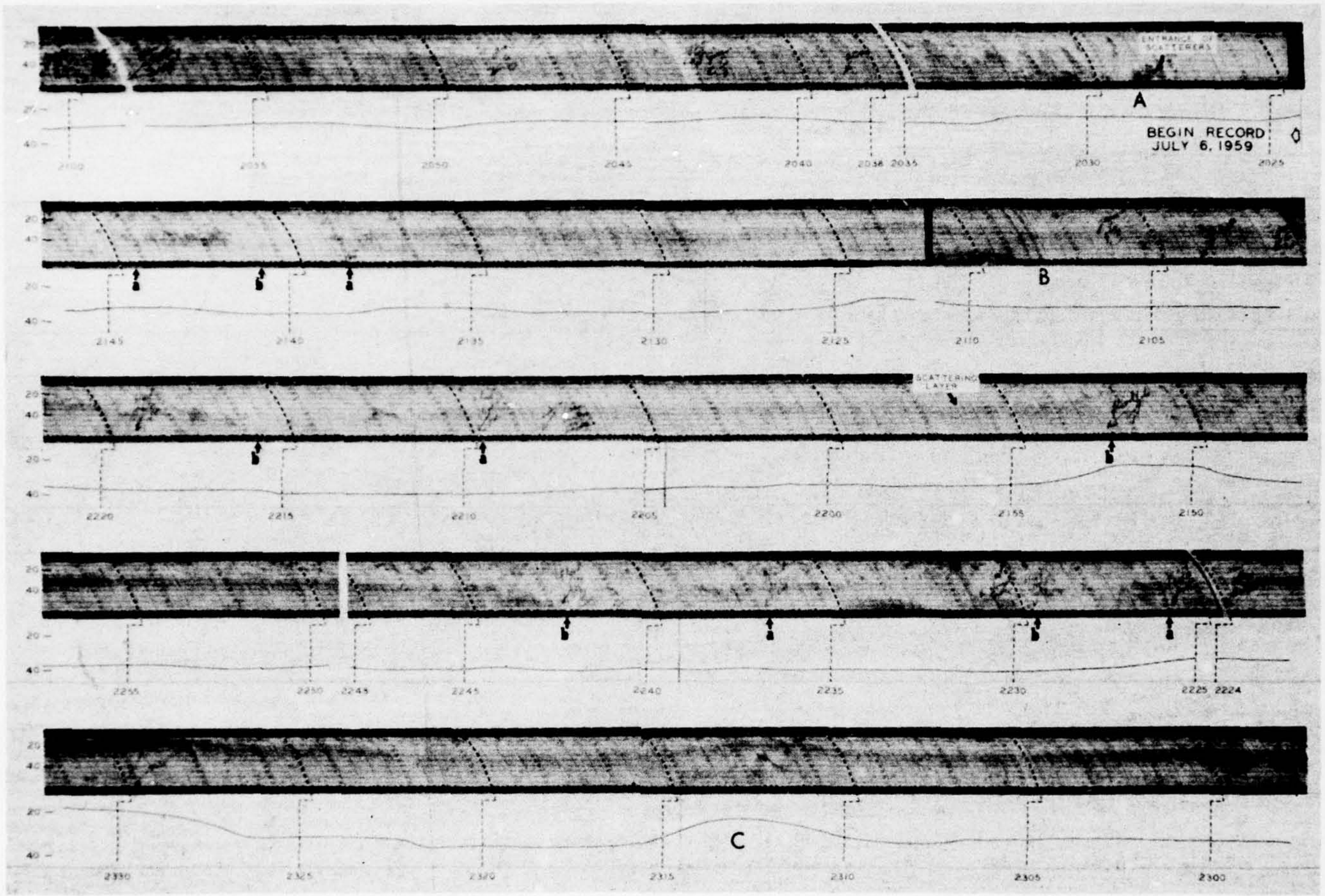

Figure 2a. (Caption next page).

Figure 2a. Echo sounder record of night scattering for 6 July 1969, from 2030 to 2330 and the corresponding vertical fluctuations of the 62° isotherm plotted below the echo sounder record, both with respect to time. The acoustic and temperature records are shown with the ocean floor appearing at the top of their respective graphs. Time, marked at the bottom of each strip, increases from right to left. Depths are plotted in feet as distances from the bottom. Point A shows the sudden entrance of the scatterers into the sound beam. The scatterers are fairly evenly distributed from about twenty-five feet above the bottom to the surface until 2106, when they form into a well-defined layer. At point B, a boat crossed over the transducer and one minute later the scattering from the bubbles in its wake can be seen to nearly block out the surface return. At point C, a large internal wave passed. The temperature structure of this wave is shown in Figure 4. At points marked (a) the spotlight was turned on and the resulting disappearance of scatterers can be seen. At points (b) the light was turned off, followed by a gradual return of sound scattering bodies.

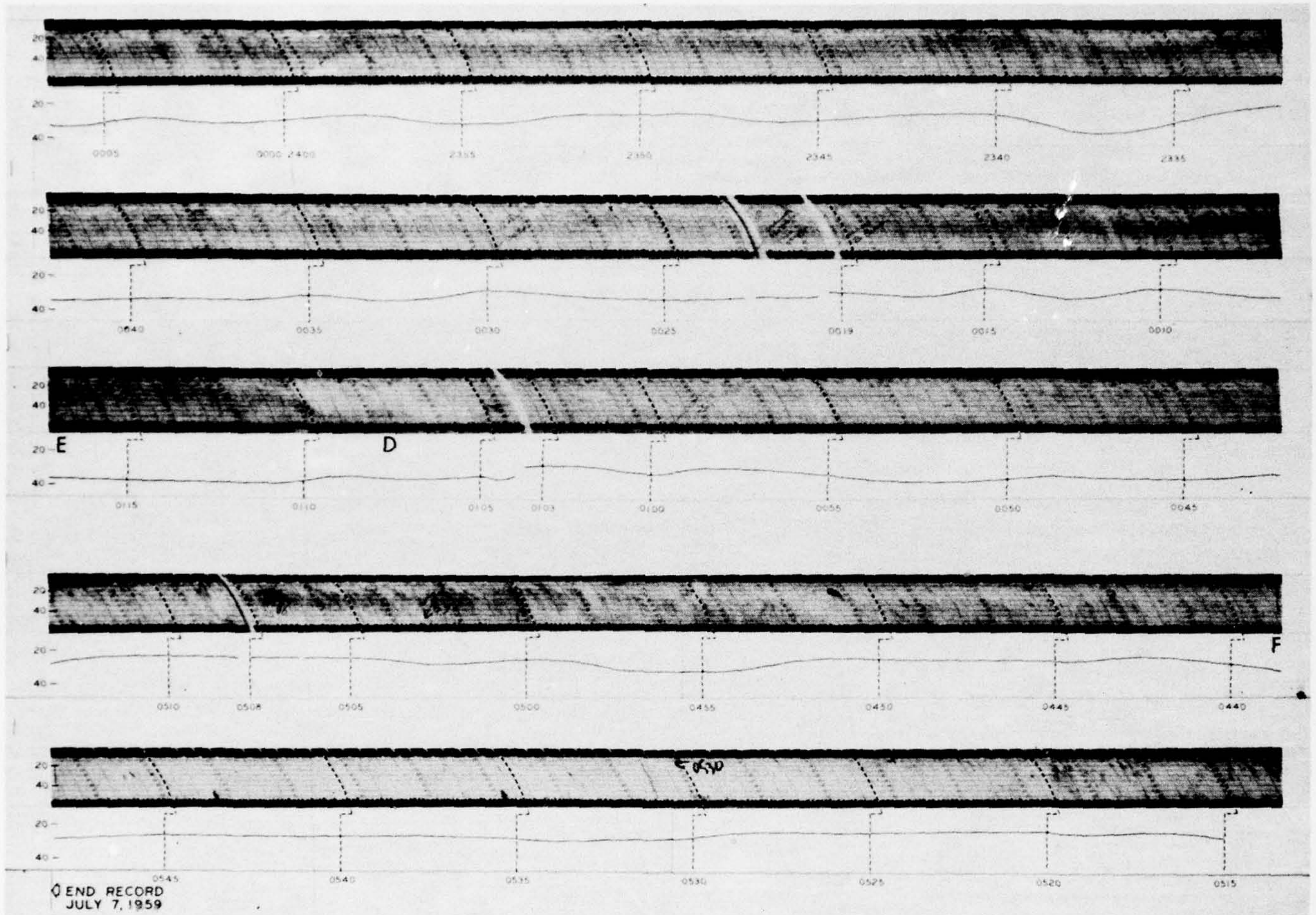

Figure 2b. (caption next page).

Figure 2b. Continuation of the record of Figure 1a. The scattering layer remains until approximately 0040, then begins to weaken. At point D, a window which was allowing a small amount of light to fall on the water over the transducer was covered, with the resulting increase in scattering intensity. Point E is the end of the first portion of the record shown. From F to the end of the record at 0548, the gradual disappearance of the scatterers with daylight can be seen.

light from the tower spotlight was observed. When the spotlight was pointed at the surface directly over the transducer and turned on, the scatterers rapidly disappeared, seeming to dive towards the bottom. As long as the light was on, the scatterers remained out of the beam. The record shows that the time interval between the point when the light was first turned on and the point where scatterers had entirely disappeared was of the order of 1 minute. This indicated that: (1) the scatterers were probably biological in nature, (2) they were capable of fairly rapid movement, and (3) their reaction to light is pronounced and immediate. After the light had been turned off again, the scatterers would rapidly return to their former position, although not as rapidly as they had disappeared. This implies that the force which caused them to form in a layer in the first place was of a strong and immediate nature.

At the same time that these observations were being taken, internal wave measuring devices were in operation at the tower. Displacements in isotherms in the water, corresponding to internal waves, were seen to closely match the vertical displacements of the scattering layer. Figures (2a) and (2b) show a comparison of the echo sounder recording with the record taken from the isotherm follower. A phase lag of about 2 minutes is apparent between the two records, due to the fact that the NK-1 transducer was located approximately 50 feet farther to seaward, the direction of approach of the waves, than was the isotherm follower recording head. Temperature data were taken

during this period with a string of thermistor beads. Figure 3 illustrates eight temperature-depth structures at selected times during the night of 6 July. The times shown were chosen for periods which were believed to be representative of the "normal" structure of the water, that is, when no internal waves were passing. Figure 4 shows temperature vs. depth curves plotted before, during, and after the very large internal wave shown at point C in Figure (2a). These curves represent 6-minute intervals. The fact that, at certain depths, considerable changes in temperature occur with the passing of a wave is quite obvious. At the approximate depth of the scattering layer before the arrival of the wave, the 6-minute fluctuation in temperature amounted to between 4 and 5 degrees Fahrenheit.

A few hours after midnight, the well-defined layer began to disappear although acoustic disturbance was still very heavy throughout the water column. The temperature plots of Figure 3 show that, during this period, the sharpness of the thermocline also began to weaken, indicating that the scatterers had previously formed into a layer on account of the presence of the thermocline. As long as the temperature gradient had been strong at a certain depth, the scatterers were confined to this level, but as soon as the sharpness broke off, they had a tendency to disperse. These results appear similar to those obtained by Lee (Ref. 14) in the English Channel. With the arrival of daylight, Tuesday, 7 July, the acoustic interferences began to gradually disappear. By sunup, the effect

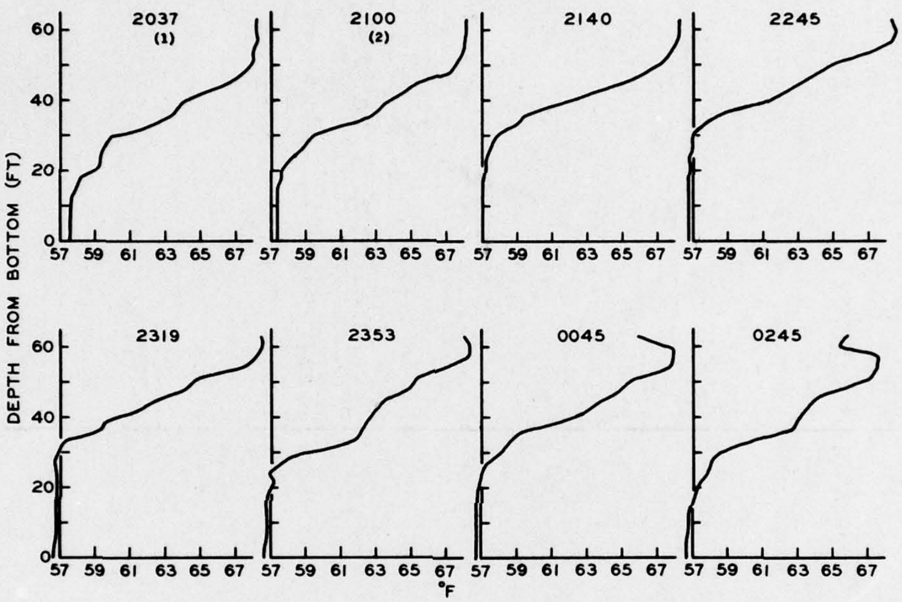

Figure 3. Graphs of temperature versus depth at selected times for the night of 6 - 7 July. Scattering layer depth for this night are shown in Figures 2a and 2b. Scattering first began about seven minutes before data for curve (1) was taken. Five minutes after the time of (2), a definite layer formed at about forty feet. After midnight, the sharpness of the thermocline began to weaken, with a subsequent dispersion of scattering intensity. These plots were made for times when no internal waves were passing.

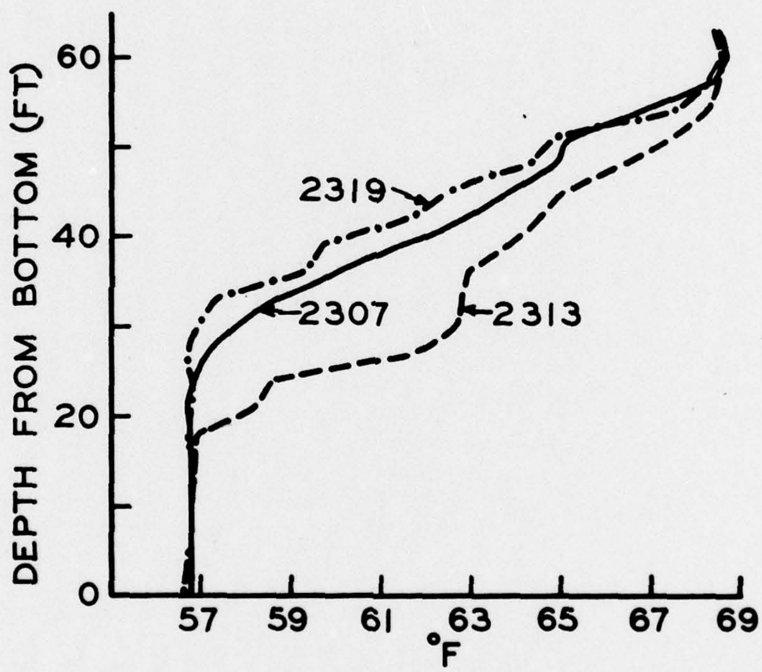

Figure 4. Three temperature-depth plots taken at six minute intervals; before, during, and after the large internal wave at point C, Figure 2a. The large temperature change at the depth of the scattering (approximately twenty-five feet from the bottom before the wave arrived) could possibly have caused the scattering organisms, or their prey, to dive in order to escape the influx of warmer water.

was entirely gone, and the echo ranger recorder once again showed the typical "clean water" daytime trace.

Tuesday night and each following night during this operation, the scattering phenomenon again appeared, quite suddenly, in the early evening hours and disappeared again before morning. None of these subsequent night records showed the well-defined layer. Each did, however, show (1) pronounced acoustic scattering in the water column; (2) a reaction of the interfering bodies to light; (3) gradual variations in depth of the intensity of the trace, indicating objects moving around in the water; and (4) correspondence between temperature structure and scattering pattern.

The distribution of the scattering seemed to vary markedly from night to night. As the illustrations show, much of Monday night was characterized by a definite layer. The Tuesday night scattering, on the other hand, appeared to be evenly distributed from bottom to surface and extremely dense. Wednesday night gave returns from near the bottom, with relatively little above this level, while the pattern for Thursday night was again one of evenly distributed scattering. These nightly differences in the overall appearance of the scattering distribution seemed to be a manifestation of the physical, chemical, and biological state of the sea as it would affect living organisms. Once the characteristic pattern had developed in the early evening, it would usually remain with only small changes for the remainder of the night, that is, sparse returns at the beginning of the night

seemed to forecast relatively sparse returns for the whole of that particular night. Returns limited to near the bottom at the outset of interference would predict mostly clear, near-surface water later on.

Period of 4 August to 7 August 1959

A period of continuous operation, beginning during the day of Tuesday, 4 August 1959 and lasting until Friday, 7 August gave results similar to those obtained in July, and in addition, demonstrated that the night scattering was normally not caused by larger fishes. Figures (5a) and (5b) are the records of the night of Tuesday, 4 August. It can be seen at point A that the entrance of the scatterers into the sound beam took place at a particular depth rather than at the bottom or throughout the water column, suggesting horizontal movement and the possibility that the scattering bodies enter as a group from another area. During the first half of the night, the layer was fairly evenly distributed from surface to bottom, with the exception of two light layers appearing at distances of 25 to 35 feet and 45 to 55 feet. A bathythermogram was taken at 2037 showing the temperature gradient to change sharply from 0.12 degrees F. per foot to 1.9 degrees F. per foot at 35 feet from the bottom, at which depth the temperature was 68 degrees. Another sharp temperature change was present at 50 feet from the bottom, and above this the water was isothermal to the surface at 73 degrees. These data show a definite correlation with the recorded scattering traces.

Figure 5a. (Caption next page)

Figure 5a. Night scattering effect for night of 4-5 August, from 2010 to 0050. Scattering begins at A, at point B, two layers can be distinguished. Temperature data for this time are described in the text. The spotlight was turned on at points (a) and off at points (b). Groups of larger scattering bodies, probably fish, can be seen starting at 0025.

Figure 5b. (Caption next page)

Figure 5b. Continuation of record of Figure 5a. Fish returns are apparent in several places; for example, notice the large region of intense returns around 0300 in which individual entities can be seen. At point C, the echo sounder was shut off temporarily. After 0400, scattering is intermittent, becoming increasingly sparse as daylight approaches.

Note the two layers at point B on Figure (5a). After midnight, layers were no longer present and the scattering pattern had begun to be mixed intermittently with regions of greater scattering density. These seemed to indicate the presence of fishes or other large targets, which were perhaps feeding on the entities providing the lighter, more homogeneous traces.

The effect of the tower spotlight on the scatterers was quite pronounced. The light was turned on at the points marked (a) on Figure (5a), and off at the points indicated by (b). The scatterers took approximately 1 minute to dive out of the light, a depth of 40 to 50 feet. The return seems to take between 1 and 3 minutes, after which they arrange themselves exactly as they had been before the disturbance. After 0400 on Wednesday morning, the scatterers began to gradually disappear, and by daylight, true to form, they were gone.

Wednesday, 5 August, the characteristic nighttime scattering was not as dense as it had been the previous night and was more evenly dispersed throughout the water column. Occasional periods of very dense returns appear in the record. These follow rather closely the sightings of large schools of 6 to 10-inch Pacific mackerel. These fish show an interesting parallel to the illumination reactions previously observed. After their appearance on the echo ranger recording, turning the light on would make the returns more dense. From four to five o'clock Thursday

morning, this school of fish was brought into the sound beam several times by turning the light on. Figure 6 shows these experiments, along with a comparison of the background returns when the fish were not present with a clear daytime record. The implication is that fishes, or at least these fish, did not cause the scattering layer return.

The following night of Thursday, 6 August to Friday morning, 7 August gave a very heavy background of scattering which was also periodically interspersed with more dense returns, closely resembling the fish returns of the previous night. Towards the middle and end of the summer, the tower began to slowly acquire its own schools of fishes; consisting primarily of Pacific mackerel (*Pneumatophorus diego*) and various species of perch. Reasons for this constant increase in the population of the water around the tower were probably the protective nature of the tower legs and the resulting increase in available food materials. Figure 7 is a daytime photo of one school of these fishes. In spite of the fact that they began to be characteristic of the water immediately surrounding the tower, discrimination could still be made between fishes and other objects by considerations of acoustic density, length of time observed, and movements of the returns.

August 18, 1959

On the evening of August 18, an attempt was made to acquire some visual observations of the scatterers. Four divers, equipped with SCUBA gear and underwater cameras, were to photograph the scatterers, while

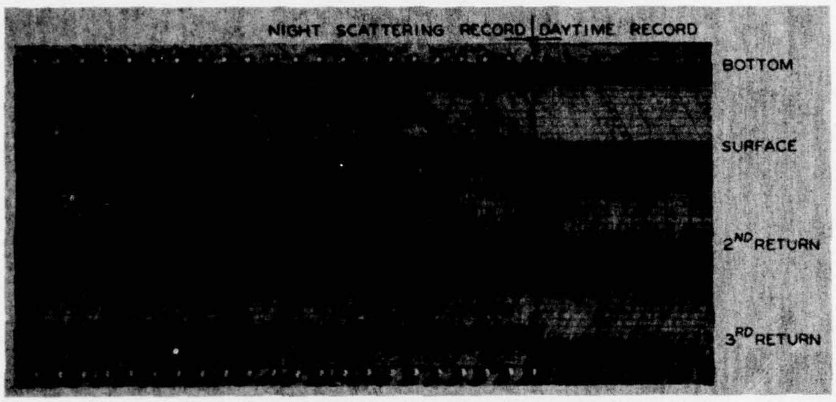

Figure 6. Record of fish in sound pattern, taken from data of the night of 5 - 6 August. On the right is a portion of the typical daytime "clean water" trace, superimposed for comparison. On the far left, many large, individual targets can be seen, some quite near to the transducer. The gain setting on the echo sounder was the same for both samples.

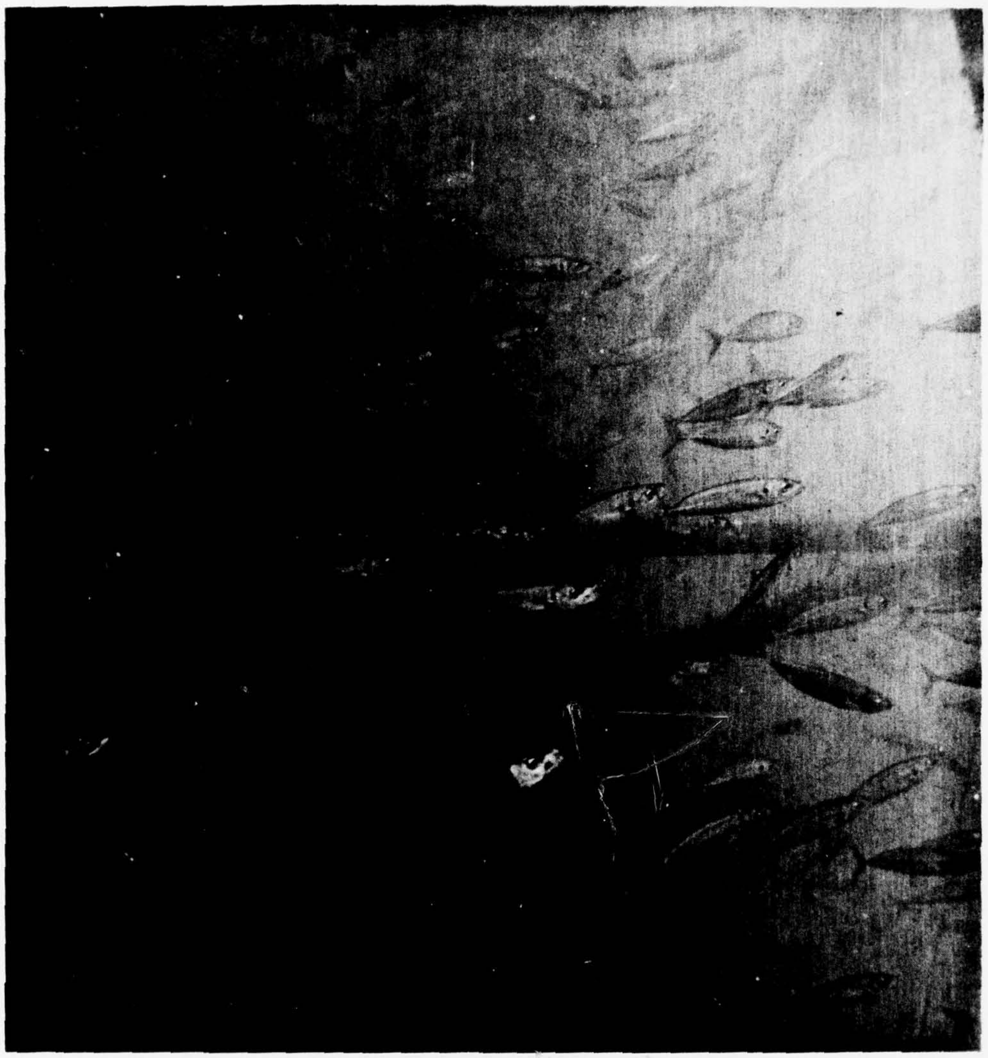

Figure 7. Photograph of some of the school of fishes which had begun to inhabit the tower region by the middle of the summer. Shown here is a group of Pacific mackerel.

the NK-1 was simultaneously making acoustic observations. The diving party consisted of Dr. Robert S. Dietz, (R. S. Dietz, "Deep scattering layer in the Pacific and Antarctic Oceans", Jour. Mar. Res., 1948); Dr. Eric G. Barham (E. G. Barham, "The Ecology of Sonic Layers in the Monterey Bay Area", Stanford University, 1957); and John A. Beagles and John R. Houchen, Jr., professional divers from the Navy Electronics Laboratory. The cameras used were a Bell and Howell 16-mm motion picture camera and a Rolliemarine underwater still camera. After each dive, descriptions of observations were recorded on a portable tape recorder.

The group arrived at the tower by boat at approximately 1935. At this time, the characteristic night scattering layer had not yet begun, and the water was relatively clear. At 2010, the scatterers arrived in the sound beam with their usual suddeness, and at 2012 and 2018, tests conducted with the spotlight showed the objects to exhibit the same negative phototaxis observed on previous occasions. All four divers, operating in pairs, began their first descent at 2031 north of the tower so as not to disturb the operation of the NK-1 transducer and test spotlight which are located on the tower's south side. During this time, the author kept track of the scatterers with the echo sounder, noting their reactions to divers' presence and to various light sources. In order to see their way around, the divers quite naturally had to use lights but a plan was formulated whereby

they would wait at various depths without lights for a period, then make *flash or floodlight* pictures. During the first dive, one reel of black and white 16-mm movie film was taken, showing dense swarms of translucent organisms, about an inch in length, near to the bottom. These were identified by Barham as mysids, which are primitive, shrimp-like crustaceans about 1/2 inch long. Two species of the mysids were present, since some were considerably larger than others. One of the species was possibly Neomysis. These animals characteristically bury themselves in sandy bottoms during the daytime probably in order to avoid predators, where they can sometimes be observed with only their eyes protruding out of the sand. Their nocturnal habits are not too generally known, but it is strongly suspected that this type of organism is a night feeder. Some doubt, however, was cast on the phototactic reaction of these mysids during the dives, and, therefore, on their contribution to the night scattering effect. They seemed to be attracted rather than repelled by the presence of the spotlight. Whether the reaction to this type of light would be different than to diffused surface light is not known. Figures 8 and 9 show two frames from the reels of motion picture film taken. Swarms of the mysids swimming rapidly in the light beam, many of them colliding with the spotlight, can be seen.

At 2247, a second dive was made, with Beagles and Houchen filming a second reel of black and white film north and west of the tower while Dietz and Barham dove on the south side in the region close to the transducer.

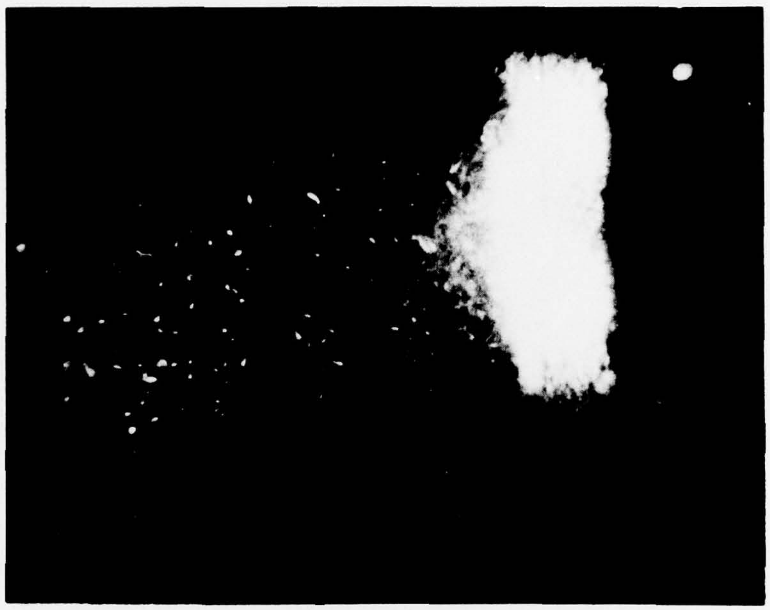

Figure 8. Photograph taken on the ocean floor, 18 August 1959, at 2040 by J. A. Beagles of the Navy Electronics Laboratory. The beam of light from the portable, underwater floodlight is shown entering from the right; at right center, one leg of the tower can be seen where it juts out of the bottom. The tower leg is sixteen inches in diameter. Many of the small (1 - 1-1/2 inch) mysids can be seen in the light, blurred by their rapid movement.

Figure 9. Another picture of the mysid swarm, indicating the density. The floodlight is visible at the left, with its beam aimed out into the water.

A faint trace of the divers' descent was picked up at this time, indicating that they were making observations quite near the sound beam, but, by the faintness, that they were far enough to the side of the transducer's central axis so as not to cause scattering in the acoustic data. After their return to the surface, the divers reported that they had observed a school of four to five hundred long silver fish, possibly silversides or topsmelt, which disappeared rapidly under the influence of their portable lights, and Dietz suggested that the phototactic effect may be due to schools of these fish. The fish were reported to be 4 to 6 inches long.

The accuracy of this conclusion would depend on (1) whether fish, capable of rapid swimming, would exhibit the consistency of daily movement associated with the night interference effect, and (2) the appearance of a school of this size on the echo sounder record, that is, whether these fish could cause the homogeneous trace which was most often obtained. Several factors tend to throw doubt on the fish theory. The author, in addition to doubting that fishes would adhere to the two conditions stated above, believes that (1) the fish observed could as easily been swimming away from the divers'presence as the presence of their spotlights, and, (2) that fishes exhibiting a negative phototaxis could swim out of the region of disturbance at a rate faster than that shown, for example, at points a in Figure (5a).

Additional Observations

Nighttime records were taken at different periods throughout the summer, with the night scattering effect being present during each instance. Near the end of the summer, during late September, the scattering density seemed on several occasions to be considerably reduced from that noticed during July and August. This suggests that the effect may be seasonal, caused by a "bloom" of certain organisms during the warmer months. This seasonal aspect, however, has not as yet been substantiated.

SUMMARY AND CONCLUSIONS

Operation of a sonic echo ranger, mounted on the ocean floor in 60 feet of water off Mission Beach, California, demonstrated the presence of substantial numbers of sound scattering bodies in coastal waters off of Mission Beach, California. Acoustic scattering was especially pronounced during hours of darkness, when certain scattering entities either move into the coastal regions from deeper water or rise up from the ocean floor. Groups of these scatterers can be observed acoustically while other stimuli are applied, and the resulting reactions noted. Using this method, the night scattering effect was determined to react to both light and temperature changes. Response to a stimulation of light was negative, the objects disappearing rapidly under the influence of a small spotlight directed into the sound beam from above the surface. Gradual appearance of daylight caused a corresponding gradual disappearance of scattering. There seemed to be

a tendency not to seek greater depths as overall illumination increased in the pre-dawn hours, but rather to slowly decrease in concentration in the volume of water being sampled by the echo sounder. These tests proved rather conclusively that the scattering bodies were actually phototactic marine organisms that followed a regular pattern of entry and exit in this region each night.

The organisms were noticed to have certain temperature-controlled reactions. The exact nature of the temperature dependency was not determined, but a definite correlation between water temperature and vertical distribution of organic scatterers could be seen. On several different occasions, the scattering effect would concentrate at regions of large temperature gradients, although this was not observed every time scatterers were present with a measurable thermocline. One answer that immediately suggests itself for this temperature seeking characteristic is the possibility that food material for the scattering organisms is sometimes present at a thermocline and sometimes not. Detailed visual observations will be needed in order to determine whether it is the scattering bodies themselves or the materials they feed on which tend to follow a thermocline, and to know whether they follow fluctuations in an isotherm because of temperature changes at a certain depth or because of the vertical transport of water in an internal wave.

The night scattering effect exhibits an unusual pattern of

movement. Entrance into the sound beam at dusk was characterized by a concentrated trace on the record, varying rapidly in depth, as if the organism were trying to organize themselves. Following several minutes of this behavior, the concentration would gradually spread out, forming into the typical, homogeneous pattern which would then last all night. Barham describes the mysids seen during the night dives as the type which characteristically bury themselves into the ocean floor during the daytime. This does not tell the whole story, however, for the records indicate not a rise from the bottom at the onset of scattering, but rather the entrance, as a group, into the tower region from another area.

The nature of the organisms involved can, to some extent, be deduced from the sounder recordings. A prominent characteristic of the night scattering effect was the homogeneity of the echoes recorded; that is, the scattering pattern never seemed to indicate that it had any specific dimensions. The implication is that the scatterers themselves looked to be homogeneously distributed to the outgoing sonic pressure waves, implying that they are present in large numbers and are somewhat smaller than the wavelength of the sound. For a signal frequency of 21 kc, the wavelength is approximately 2-3/4 inches. Targets larger than 4 to 6 inches, such as large fishes, could be expected to appear on echo sounder traces as dark, fast-moving patches, appearing and disappearing on the record. This was indeed shown to be the case as the various illustrations point out. The fact

that these dark-patched traces were larger fishes and that the night interference was caused by different type of organism was further substantiated by the positively phototactic reaction of larger scatterers, readily attributed to fishes common to this area by visual observations at the surface. However, a very large school of smaller fishes could be responsible for the scattering; the main criterion would be the regularity of their nocturnal activity. The author believes that this phenomena cannot be attributed to any one type of organism alone, due to the complexities of food chains in the sea and to the multiplicity of layers sometimes seen during the periods of observation.

The question arises as to a reason for the daily movement. It seems quite possible that certain regions of the ocean floor fill the requirements for a daytime habitat for these scattering organisms, while other areas are preferred for night feeding. The tendency to move as a group, if such is the case, needs still more explanation, and a continued program of research is underway at the tower location to provide answers to such questions. Among other plans, high resolution sounding devices and underwater photographic equipment permanently mounted on the tower legs are envisioned to obtain records of the movement and habits of these biological, sound scattering entities.

The regularity of the night scattering seems to be its most important characteristic as far as the effect on the acoustic environment of this

region is concerned. Because of the nightly appearance of these scatterers, the shallow waters off Mission Beach, and very probably many other coastal regions, are rendered much less conducive to acoustic ranging during hours of darkness than for the period from early dawn to late afternoon. The extent of the scattering at night may sometime in the future be predictable by knowing such parameters as water temperature, ambient atmospheric lights, and the habits of these sound scattering organisms.

ACKNOWLEDGMENTS

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